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NTOF-20M-IGNHI: A PRIMER AND SHORT HISTORY OF THE DETECTOR (OCTOBER 2013)

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NTOF-20M-IGNHI

A primer and short history of the detector (October 2013)

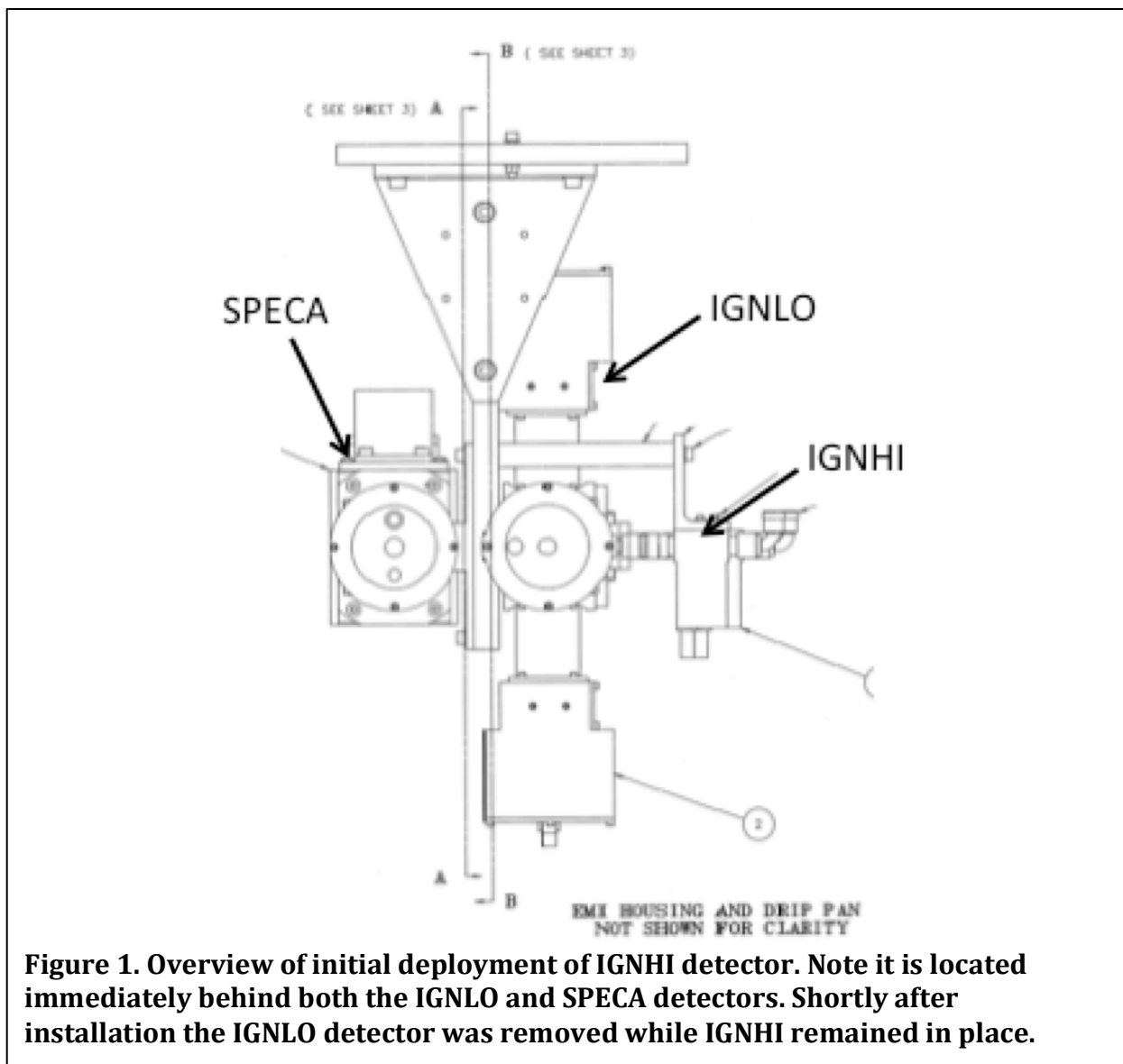
James McNaney

ABSTRACT

This document describes the NTOF-20M-IGNHI detector and documents its general capabilities and history of use at NIF

General History

NTOF-20M-IGNHI is a detector consisting of four (4) independent diamond detector elements: two 10mm diameter X 1mm thick diamonds (DET2, DET3), one 24mm diameter X 1mm thick diamond (DET1), and one 5mm diameter X 0.25mm thick diamond (DET4). The detector in its initial deployment is shown in figure 1. The distances from TCC to the



front face of the diamonds was 23.392m, 22.384m, 22.384, and 22.387m for DET1-DET4 respectively.

The detector was originally installed in the neutron alcove along line of sight 116-316 (actual LOS is 114.5, 319) and was part of a three detector closely coupled group (SPECA, IGNLO, IGNHI). Shortly after installation, the IGNLO detector was removed from the group leaving only SPECA and IGNHI. Each detector element had a cable path of approximately 40m connected to its own Tektronix 7104 digitizer. The digitizers were contained within

an EMI enclosure located diagnostic mezzanine DM1 lower. A schematic of the recording system for the initial deployment is shown in figure 2.

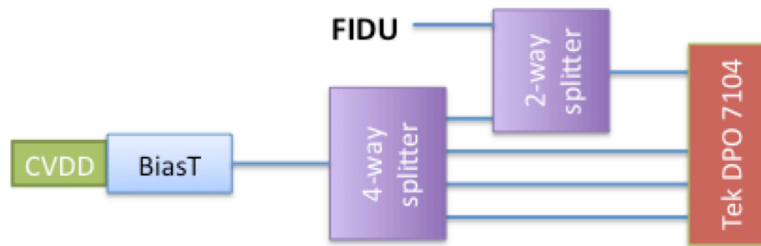


Figure 2. Overview of recording system for initial installation of IgHi. DET1 represented in full, DET2-4 have identical recording systems.

In May of 2012 the IGNHI detector was upgraded and reconfigured as part of a larger LOS upgrade to address a number of issues including minimization of SPECA detector housing mass, replacement of the SPECA scintillator, re-installation of the 4M-BT detector on the same LOS (in 64, 136), separation of the SPECA and IGNHI detectors (by moving IGNHI back to 27m from TCC), relocation of the digitizers to the alcove, and remounting of the CVDD diamond bias tees to a location out of the collimated neutron beam. The latter change was designed to address the generation of signal in the bias tee due to neutron interactions. While these interactions are known to be very small for the higher sensitivity diamonds (10mm and 24mm), the change was in preparation for eventual ignition level yields for which a lower sensitivity diamond was to eventually be installed. A schematic of the redesigned IGNHI detector is provided in figure 3 while the revamped recording system is shown schematically in figure 4. Note the CVDD detectors are in different positions relative to the original installation. The distances from TCC to the front face of the diamonds are 27.220m, 27.220m, 27.214, and 27.215m for DET1-DET4 respectively.

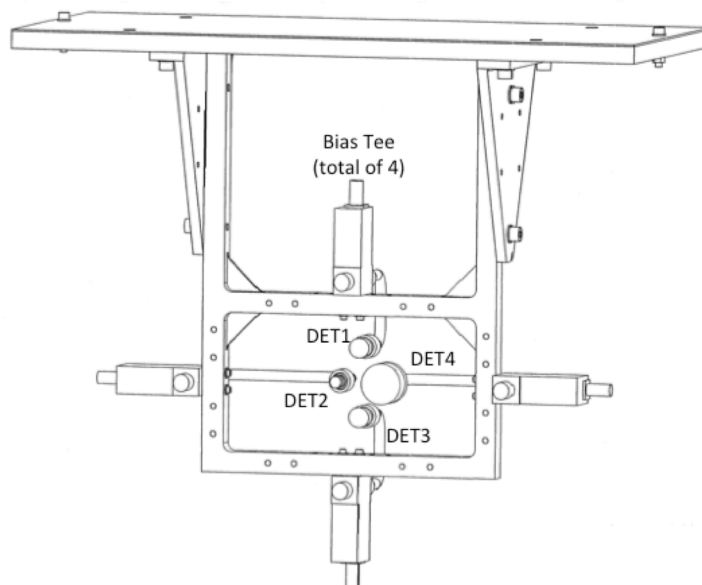
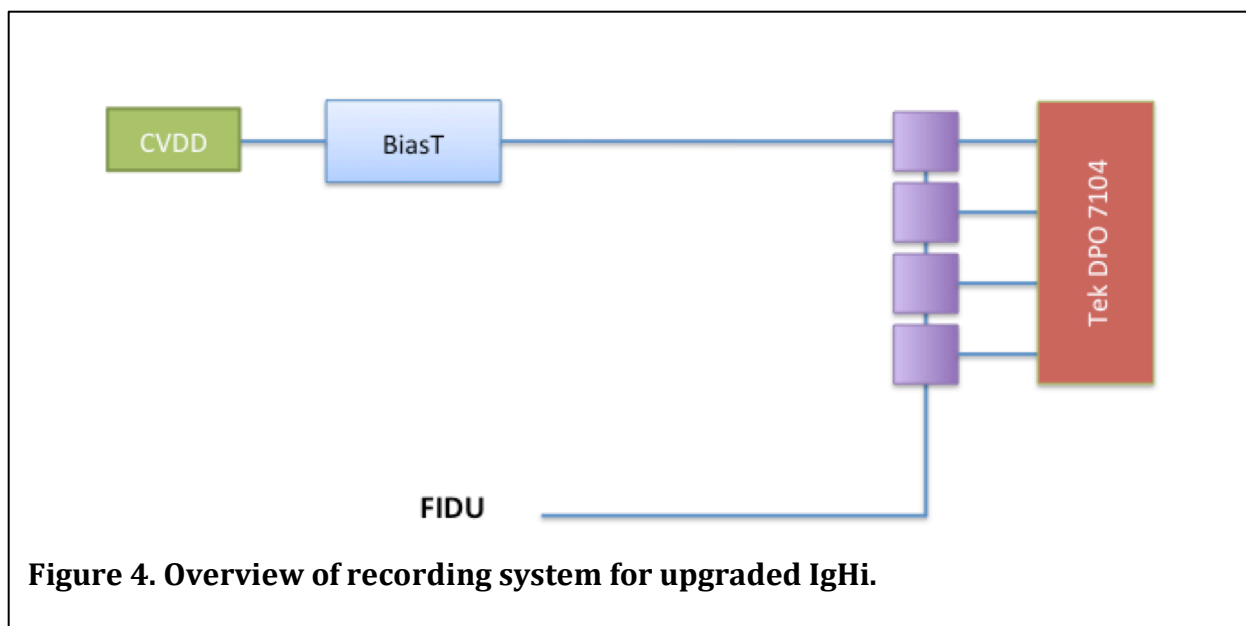


Figure 3. Overview of upgraded IgHi detector.



As part of the IGNHI relocation and redesign, provision was made to mount the detector in either of two positions, one immediately behind the SPECA detector (near) and one approximately 5m behind the SPECA detector (far). The near position was provided to allow cross-timing of the two detectors on neutrons shots such that the pair of detectors might be used to measure the velocity of the neutron emitting region when the IGNHI detector is located in the far position. It has subsequently been shown that the measurement can be made using the SPEC detectors alone.

Construction of IRF

The construction of the IRF for NTOF-20M-IGNHI utilizes the same general steps as for other NTOF detectors: measurement of an x-ray IRF and convolution with an MCNP simulation of neutron impulse generated signal. A brief discussion follows.

X-ray Impulse Response

Due to the small solid angle covered by the IGNHI CVDD detectors, it is not possible to measure an X-ray response in-situ at NIF. X-ray response has been obtained at the COMET laser a short pulse (1ps) moderate energy (6-10J) laser system located at the Jupiter Laser Facility.

Pre-upgrade x-ray IRF

X-ray IRFs for the initial installation of IGNHI were obtained from two different sources. The 24x1mm CVDD xray IRF was obtained from COMET experiments as described below but in a configuration matching the pre-upgrade configuration (e.g., diamond mounted directly to the bias tee). The 10x1mm and 5x0.25mm CVDD xray IRFs were assumed to be the same as those measured in the NTOF4-BT detector. The COMET based x-ray IRF for the pre-upgrade 24x1mm CVDD is shown in figure 5. The FWHM is 4.2ns. All X-ray IRFs had exponential extrapolations of the late response as the dynamic range of the underlying data was too limited to allow long time construction.

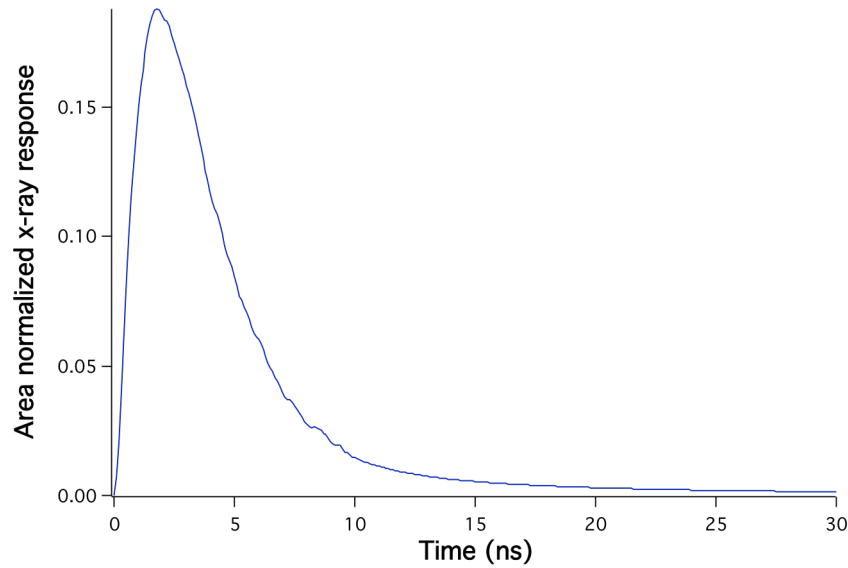


Figure 5. Area normalized impulse response measured at the COMET laser for the 24x1mm CVD diamond in a pre-upgrade configuration.

Post-upgrade x-ray IRF

Post-upgrade x-ray IRFs were obtained from COMET based data using surrogate cabling of the same total length as is deployed in the NIF facility. Data to date has only been acquired on DET1, DET2, and DET4. Each of these detectors, along with its bias tee and u-shaped connector, were used in generating the x-ray impulse data. Due to the poor SNR of the COMET data the IRF falls rapidly into the noise floor of the recording system. Data for DET1 and DET3 (the 10x1mm CVD diamonds) is presented in figure 6, while the data for the 24x1mm CVD diamond (DET4) is shown in figure 7. FWHM values are 0.087 ± 0.02 ns, 1.25 ± 0.02 ns and 3.70 ± 0.11 ns for DET1, DET2 and DET4 respectively.

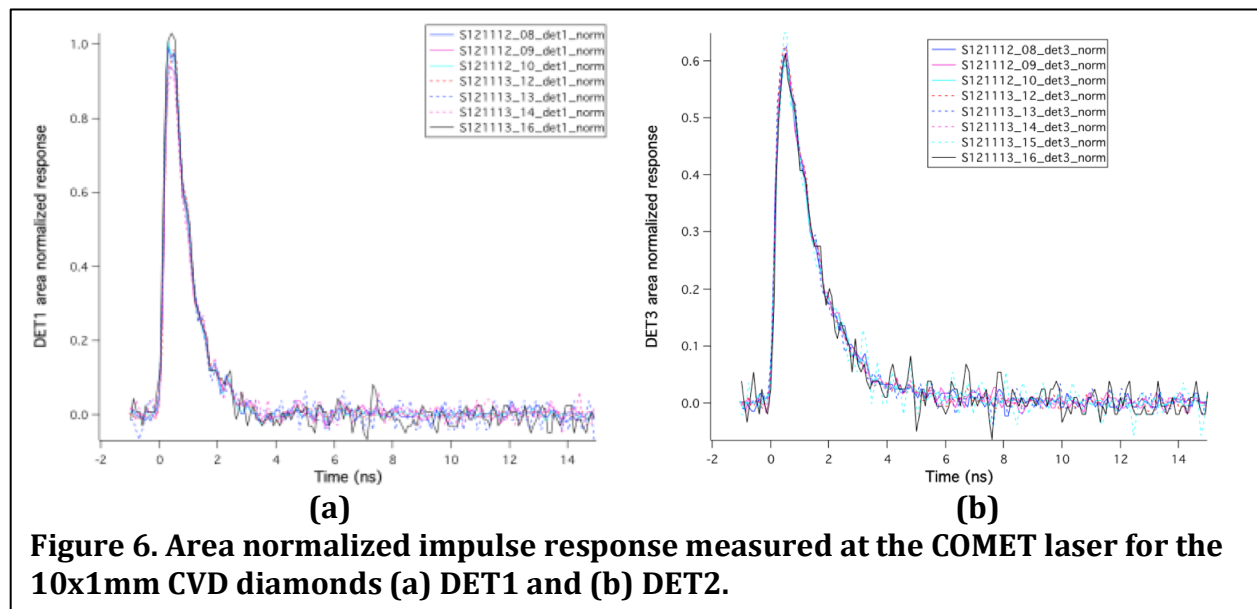
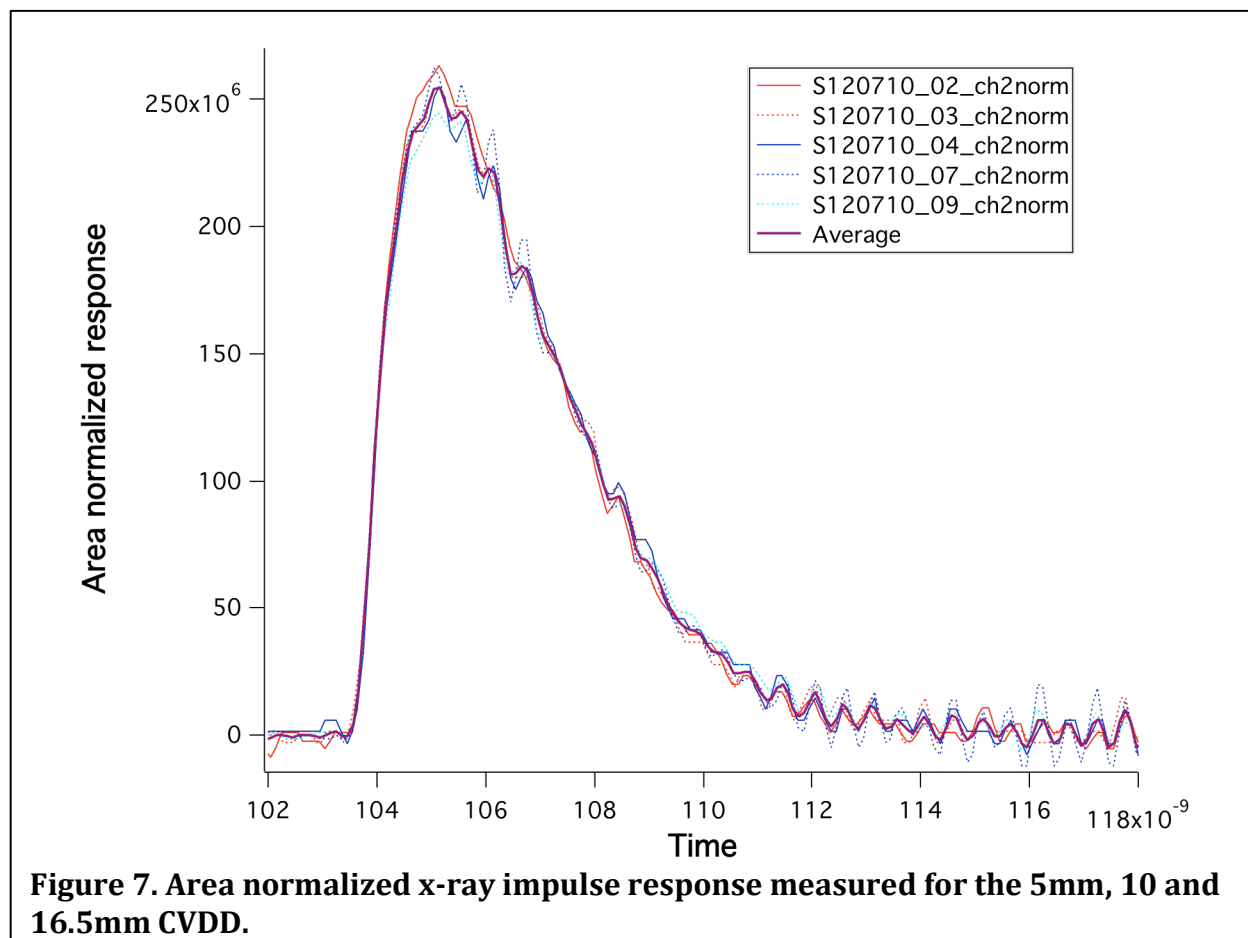


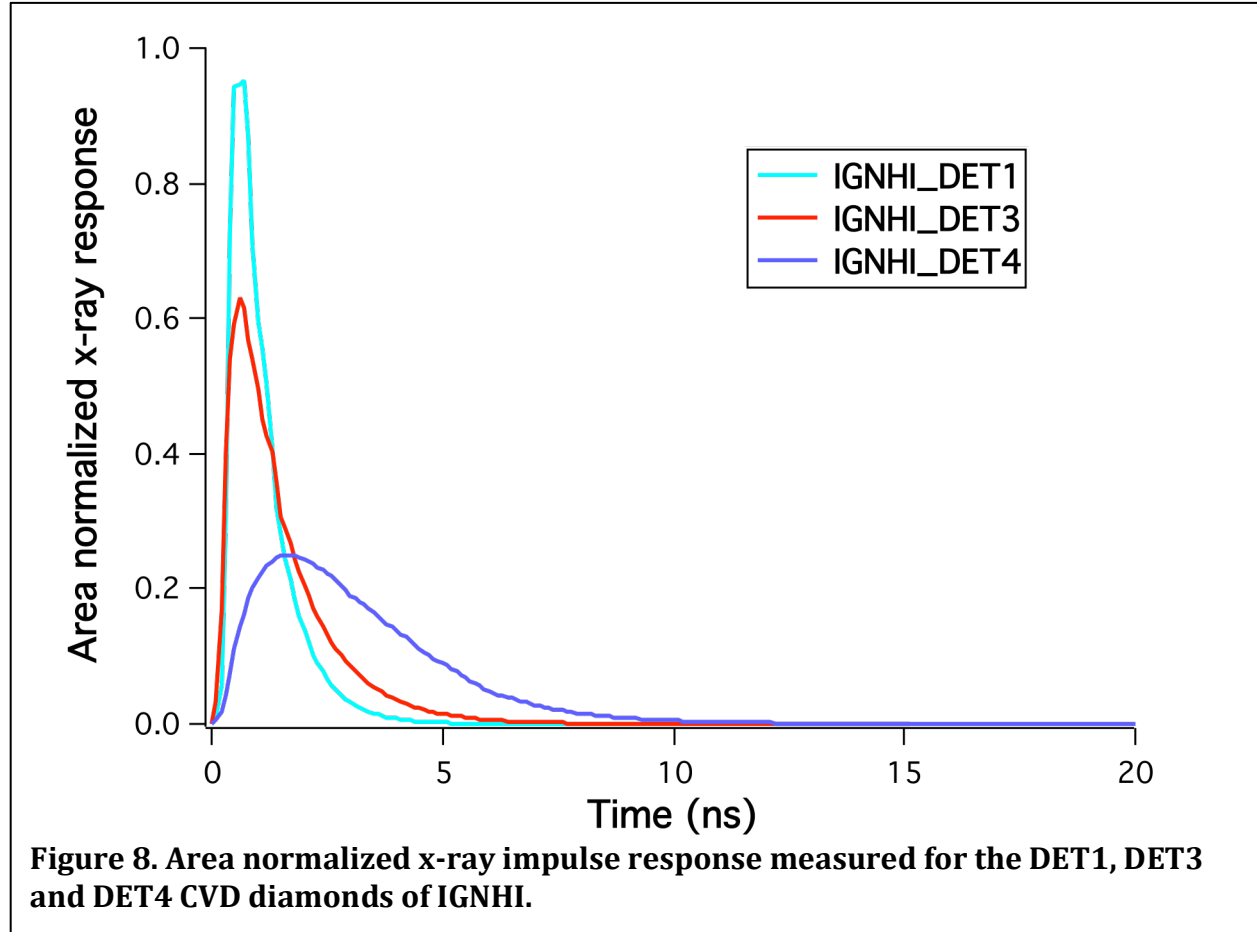
Figure 6. Area normalized impulse response measured at the COMET laser for the 10x1mm CVD diamonds (a) DET1 and (b) DET2.



In order to create smoother versions of the x-ray IRFs different strategies were employed for the 10x1mm and 24x1mm CVD diamonds. For the 10x1mm diamonds a single exponential fit was carried out on the falling edge of the COMET data. This fit was found to be excellent and forms the basis of the IRF for times beyond 1.3ns for DET1, and 1.4ns, for DET3. A high frequency noise component is readily visible in the data for the 24x1mm CVDD. The final IRF was constructed in the following way. The rising edge of the data is used as the basis of the IRF up to 0.6ns. Between 0.7 and 7ns a filtered version of the IRF was used in place of the data. The filter was a low pass filter that resulted in the removal of the high frequency component from the data. A second filtered version with a much lower pass frequency was used for the region from 7-12ns. Finally, an single exponential tail was fit to the 7-10ns region and the extrapolation forms the remainder of the IRF for times greater than 12ns. In both the 10x1 and 24x1 CVDD cases the final versions are a faithful representation of the data. A summary plot of the final x-ray IRFs is shown in Figure 8.

One significant event should be noted with regard to the DET1 CVDD. The originally installed bias tee was found to have failed at some point during the upgrade activities. During the troubleshooting process the diamond detector holder was disassembled and the diamond was inspected under a stereomicroscope while illuminated by a high intensity halogen lamp. Subsequently the DET1 diamond was found to be less sensitive and have a

narrower x-ray IRF (see figure 7). While the reasons for these changes are beyond the scope of this note, they can be anticipated from trap clearing arguments present in the literature. These changes are a stark illustration of the effects seen in the NTOF4-BT detector.



MCNP simulations

Two MCNP models of the detector have been made. One model was constructed by J. Caggiano, and corresponds to the pre-upgrade condition, while the second model was constructed by Hesham Khater for the post-upgrade deployment. Both have simulated the time-domain response to a 14.03MeV neutron source. The Tally was divided into both energy and time bins for both neutrons and photons. Time bins in the simulation were not evenly spaced with very short bin spacing over the peak of the impulse arrival and increased bin width with increasing time. The total energy deposition was based on Tom Phillips' carbon sensitivity calculation for neutrons. No photon dependence has been included as the level of energy deposition due to photon was 2-3 orders of magnitude lower than that of the neutrons. Summary plots of the MCNP simulations are shown in figure 9. For the post-upgrade configuration note the increase in energy absorbed that occurs approximately 70ns after the initial arrival of the neutrons. This increase is due to

the neutrons scattered at the back wall of the alcove, located approximately 2m behind the detector.

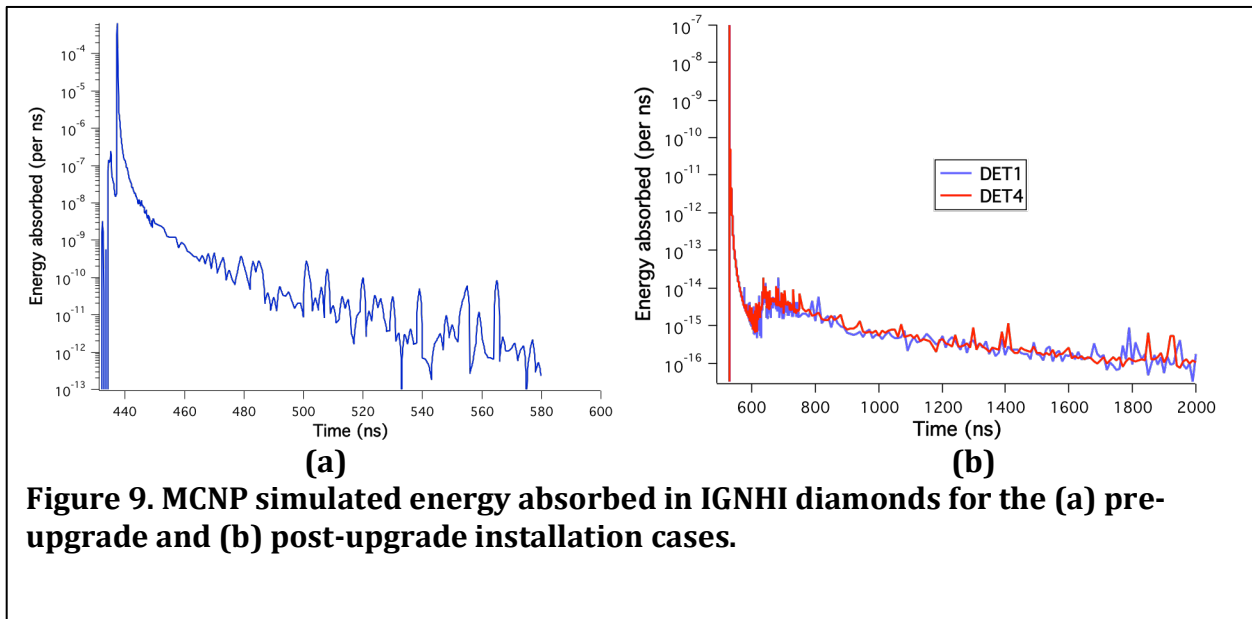


Figure 9. MCNP simulated energy absorbed in IGNI diamonds for the (a) pre-upgrade and (b) post-upgrade installation cases.

Neutron IRFs

Final IRFs were constructed by convolution of the MCNP simulations and the x-ray IRFs. Small differences in the simulations done for the pre- and post-upgrade configurations are noted below.

Pre-upgrade

The MCNP simulation for the pre-upgrade configuration utilized a relatively coarse 0.1ns time bin over the arrival time of the 14.03MeV neutrons and contained a tally for the 24mm CVDD only. Given that the transit time of the neutron through a 1mm diamond is ≈ 20 ps, the details of the response during this transit are obviously not contained in the IRF. However, this is unlikely to affect the accuracy of the response function as the width contribution from this transit is very small compared to the overall width of the response function and the TOF spectrum width at the detector location. As well, the MCNP results were smoothed in the late time tail by fitting with an exponential function. Convolution maintained the 0.1ns time binning and no interpolation was used. MCNP tally results for the 24mm CVDD were used for all CVDD detectors.

Post-Upgrade

The MCNP simulation for the post-upgrade configuration utilized variable time binning with 10ps bins surrounding the arrival time of the 14.03MeV neutrons. Tallies were made for each CVDD detector. All data were interpolated onto a 1 ps time base to allow use of the fine-binned MCNP simulation results. Subsequent to convolution the data were re-binned to 0.1ns bin spacing. Re-binning was done such that the integral is conserved throughout the time domain. Final IRFs are shown in figure 10. As no x-ray data has been taken for the 5mm CVDD (DET2) there is no neutron IRF.

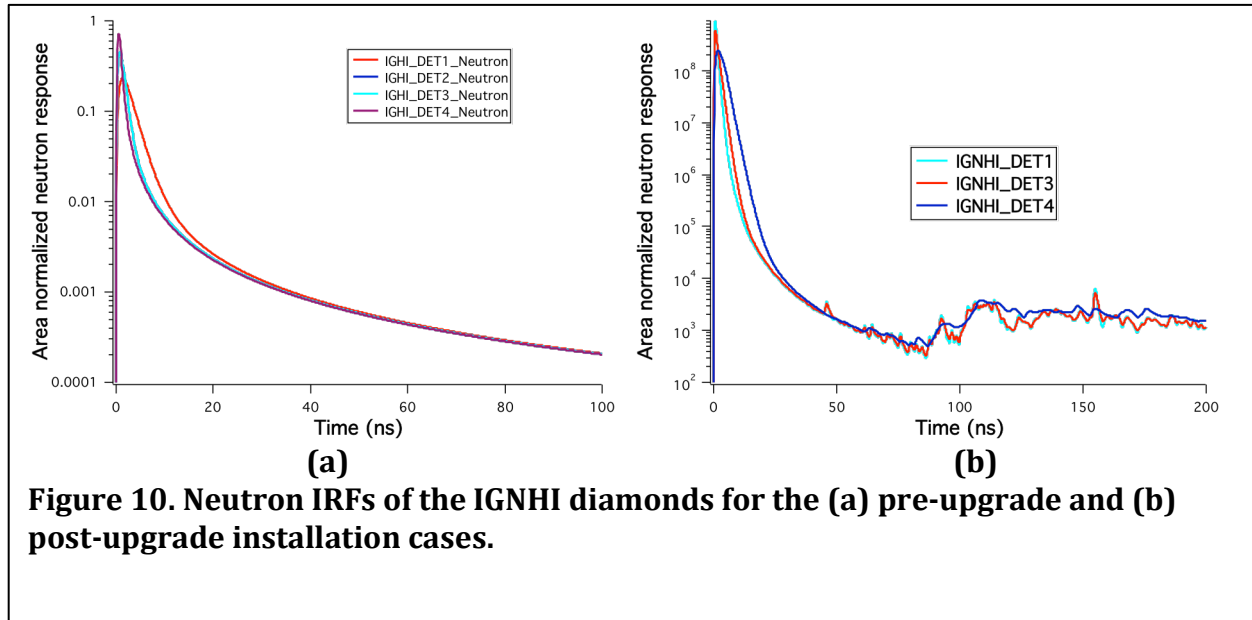


Figure 10. Neutron IRFs of the IGNHI diamonds for the (a) pre-upgrade and (b) post-upgrade installation cases.

Yield calibration

Yield calibration for NTOF-20M-IGNHI follows the same methodology used in other NTOF diagnostics: comparison of the charge associated with the fitted neutron distribution with activation diagnostic results on exploding pusher shots. As there are no changeable components (save attenuators) the process is straightforward. Absolute calibration accuracy is in the 8% range while shot-to-shot variability was shown to be 3% or better based on early shot data analysis (shown in figure 11) that compared results from multiple diamond detectors on single shots. Note that IGNHI has also seen some yield variability, though somewhat less than that shown by NTOF4-BT.

Current status of diagnostic

Recently the use of NTOF-20M-IGNHI has been limited by the reallocation of 3 oscilloscopes to the SpecA and SpecE system upgrades. Only DET4, the 24x1mm CVDD, is currently (130927) operational.

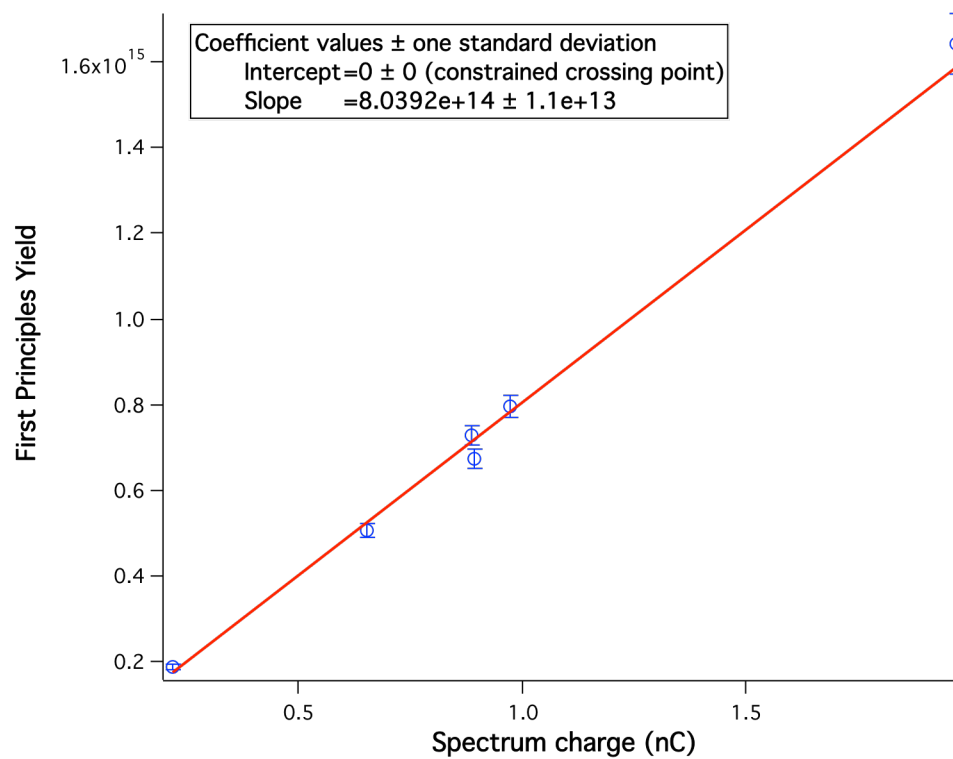


Figure 11. Most recent yield calibration for IgHi (27m position).